Appendix H. Memorandum Regarding cPAHs in LDW Clam Siphon Skin

MEMORANDUM

To: Elly Hale, EPA
From: Windward on behalf of LDWG
Subject: Clam sampling results for cPAH analysis of siphon skin
Date: August 7, 2017

As discussed in the Lower Duwamish Waterway (LDW) human health risk assessment (HHRA) and remedial investigation (RI) (Windward 2007, 2010), at least 95% of the risk to human health from arsenic and carcinogenic polycyclic aromatic hydrocarbons (cPAH) associated with seafood consumption is from the consumption of clams. The Regional Applied Research Effort (RARE) study conducted in the LDW found that inorganic arsenic concentrations detected in siphon skin (19.0 to 65.0 mg/kg wet weight [ww]) were significantly higher than those detected in main-body tissue (0.02 to 0.09 mg/kg ww) (Kerns et al. 2017). However, no information was obtained regarding the relative cPAH toxic equivalents (TEQs) in siphon skin and main-body clam tissue.

Thus, in order to determine if significant differences exist between cPAH TEQs in clam siphon skin and those in main-body clam tissue (as was the case for inorganic arsenic), clams were collected from three areas in the LDW. These clams were sent to Analytical Resources, Inc. (ARI) for cPAH analysis of siphon skin and main-body clam tissue; this memorandum summarizes the resultant data. This information allows for a determination of whether siphon skins should be analyzed separately from whole-body tissue in the baseline clam tissue investigation proposed in the Work Plan (Windward and Integral 2017).

FIELD COLLECTION

Softshell clams (*Mya arenaria*) were collected during low tide on June 26, 2017 per the sampling memo (Attachment 1). Three sampling areas were targeted for the collection of clams based on the clamming areas identified in the RI (clamming area 3, northern clamming area 11N, and southern clamming area 11S) (Map 1). However, the field crew was unable to find sufficient clams in clamming area 3, so clamming area 6 was selected as an alternative location. The target and actual clamming areas are described in Table 1 and shown on Map 1. The majority of clams were collected near the low tide line.

Table 1. Clam collection areas

Clamming Area	RM	No. of Clams Collected	Description of Substrate/Area
Clamming area 3	0.6 (west side of waterway)	0	The top 10 cm were unconsolidated silt and fine sand, with anoxic, hard-packed fine sand and silt below that. Brick debris was observed near the surface with wood debris below.
Clamming area 6	2.1 (west side of waterway)	20	fine to medium sand with some silt; approx. 30 ft of beach.
Clamming area 11 (north)	3.8 (east side of waterway)	19	silt and fine sand; some cobble; approx. 50 ft of beach.
Clamming area 11 (south)	3.8 (east side of waterway)	20	silt and fine sand; approx. 50 ft of beach.

RM – river mile

Upon completion of the sampling effort, all of the *M. arenaria* clams were transported and stored, refrigerated at < 6°C, overnight at Windward Environmental LLC (Windward) prior to transport to ARI.

LABORATORY PROCEDURES

Removal of the clam tissue from the shell and separation of the siphon skin from the main body of the clam were performed at ARI on June 27, 2017. Technicians wore powder-free, nitrile examination gloves, and used equipment that was cleaned (detergent wash, acid rinse, and deionized water rinse) between composite samples to avoid contaminating tissue samples during sample handling and processing.

Two composite samples (i.e., one siphon skin and one remainder tissue) were created from 15 clams collected from each site. Clams selected for tissue compositing and analysis were measured to confirm that they met the minimum width requirement of 2 cm prior to processing (Figure 1). Clams were rinsed with deionized water and opened, and all of the soft tissue was removed from the shell; the siphon skin was then carefully dissected from the main-body tissue. The individual siphon skin and remainder tissue samples were rinsed with deionized water and weighed prior to being placed in glass jars. The individual siphon skins and remainder tissues for each location were combined to create, respectively, a siphon skin composite sample and a remainder tissue composite sample for each location. Composites were homogenized by the laboratory and analyzed for the parameters listed in Table 2.

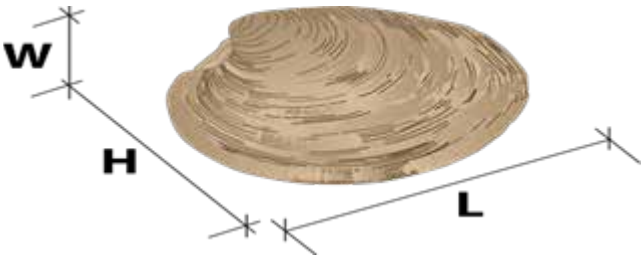


Figure 1. Clam dimension measurements

Table 2. Analytical methods

Parameter	Method	Reference
PAHs	GC/MS	EPA 3350-C Mod/EPA 8270D-SIM
Lipids	gravimetric extraction	Bligh and Dyer (mod)
Percent solids	drying oven	PSEP (1997)

EPA – US Environmental Protection Agency
GM/MC – gas chromatography/mass spectrometry
PAH – polycyclic aromatic hydrocarbon
PSEP – Puget Sound Estuary Program
SIM – selected ion monitoring

RESULTS

The average clam size and average tissue mass for each composite sample are provided in Table 3. The size of each individual clam and the mass of the tissue associated with that clam are provided in Attachment 2. The clams in all three composite samples were similar in size, which was measured as width of the shell and mass of the tissue. The average siphon tissue represented between 10 and 18% of the total clam tissue mass for the clams in each of the composite samples.

Table 3. Average clam size and average tissue mass for each composite sample

Sampling Location	No. of Clams in Composite	Average Clam Shell Width (cm)	Average Tissue Mass (g ww) (remainder)	Mean Siphon Tissue Mass (g ww)	Mean Siphon Tissue Mass as % Total Mass
C-6	15	3.00	14.99	2.45	10
C11N	15	2.94	17.23	3.82	18
C11S	15	2.80	15.64	2.91	16

ww – wet weight

Two tissue composite samples were created for each location, one composite of clam siphon tissue and one composite of remainder tissue, for a total of six tissue composite samples. Each of the six composite samples were analyzed for polycyclic aromatic hydrocarbons (PAHs). Detection frequencies and concentrations across all six composite

samples are summarized in Table 4. cPAH data for each composite sample are provided in Table 5, and results for all individual PAH compounds and PAH sums are provided in Attachment 2.

Table 4. Summary of PAH concentrations in clam tissue samples

Analyte	Detection Frequency	Minimum Detected Concentration (µg/kg ww)	Maximum Detected Concentration (µg/kg ww)	Minimum Reporting Limit (µg/kg ww)	Maximum Reporting Limit (µg/kg ww)
1-Methylnaphthalene	0/6	nd	nd	0.47	0.49
2-Methylnaphthalene	0/6	nd	nd	0.47	0.49
Acenaphthene	3/6	0.87	1.33	0.49	0.49
Acenaphthylene	0/6	nd	nd	0.47	0.49
Anthracene	6/6	0.50	1.34	na	na
Benzo(a)anthracene	6/6	1.84	6.80	na	na
Benzo(a)pyrene	6/6	2.10	5.86	na	na
Benzo(b)fluoranthene	6/6	2.97	7.20	na	na
Benzo(g,h,i)perylene	6/6	2.53	8.57	na	na
Benzo(j)fluoranthene	6/6	1.23	3.29	na	na
Benzo(k)fluoranthene	6/6	1.32	3.66	na	na
Chrysene	6/6	2.74	8.63	na	na
Dibenzo(a,h)anthracene	4/6	0.52 J	1.72 J	0.47	0.49
Dibenzofuran	3/6	0.51	0.73	0.49	0.49
Fluoranthene	6/6	4.85	20.3	na	na
Fluorene	3/6	0.89	1.39	0.49	0.49
Indeno(1,2,3-cd)pyrene	6/6	1.11	5.97	na	na
Naphthalene	0/6	nd	nd	0.56	0.59
Phenanthrene	6/6	1.56	7.12	na	na
Pyrene	6/6	4.63	16.9	na	na

J – estimated concentration
na – not applicable
nd – not detected
PAH – polycyclic aromatic hydrocarbon
U – not detected at given concentration
ww – wet weight

Table 5. cPAH TEQs in clam siphon and remainder tissue samples

Sample Name	Clam Tissue Sampling Location	Matrix	cPAH TEQ (ug/kg ww) (clam tissue)
LDW17-C06-MARM-Comp01	6	clam remainder	5.0 J
LDW17-C06-MAST-Comp01	6	siphon skin	3.0 J
Estimated whole-body concentration[a]			**4.8 J**
LDW17-C11N-MARM-Comp01	11 (north)	clam remainder	4.3
LDW17-C11N-MAST-Comp01	11 (north)	siphon skin	8.3
Estimated whole-body concentration[a]			**5.0**
LDW17-C11S-MARM-Comp01	11 (south)	clam remainder	3.5
LDW17-C11S-MAST-Comp01	11 (south)	siphon skin	5.1 J
Estimated whole-body concentration[a]			**3.8 J**

[a] Estimated whole-body concentration calculated based on mass-weighted average concentration. The average mass fractions of siphon skin and remainder tissue for each composite sample were used to calculate the estimated whole-body concentration for the composite.

cPAH – carcinogenic polycyclic aromatic hydrocarbon
J – estimated concentration
TEQ – toxic equivalent
ww – wet weight

As shown in Table 5, cPAH TEQs in the siphon skin and remainder tissue composites were similar to each other in the three sampling areas, demonstrating that cPAHs are not being preferentially accumulated in siphon skin. In addition, the cPAH TEQs were similar across the locations, with TEQs ranging from 3.0 to 8.3 µg/kg ww in the two tissue types, and from 3.8 to 4.9 µg/kg ww in the estimated whole-body concentrations.

No sediment data were collected as part of this investigation. Based on RI data collected in the vicinity of the clam sampling areas (Map 1), cPAH TEQs in sediment samples closest to the clam collection locations ranged from 54 to 6,600 µg/kg dry weight (dw), with the lowest concentration associated with clamming area 6 and the highest concentration associated with clamming area 11 (Table 6). No RI clam tissue data are available for clamming area 11; clams collected in clamming area 6 had a cPAH TEQ of 10 µg/kg ww, relative to the cPAH TEQ of 4.7 µg/kg dw measured as part of this investigation.

Table 6. cPAH TEQs in clam tissue and sediment samples from the LDW RI

Clam Tissue Sampling Location	This investigation	Existing RI data (Windward 2010)	
	cPAH TEQ (ug/kg ww) in Clam Tissue	cPAH TEQ (ug/kg ww) in Clam Tissue	cPAH TEQ (ug/kg dw) in Surface Sediment
6	4.8 J	10	54–120 (n = 5)
11 (north)	5.0	na	1,500–1,800 (n = 2)
11 (south)	3.8 J	na	1,900–6,600 (n = 4)

cPAH – carcinogenic polycyclic aromatic hydrocarbon
dw – dry weight
J - estimated
LDW – Lower Duwamish Waterway
na – not available
RI – remedial investigation
TEQ – toxic equivalent
ww – wet weight

DATA QUALITY REVIEW

In lieu of formal data validation, the laboratory quality assurance (QA) results were reviewed. Samples were prepared and analyzed within recommended holding times. All sample analysis met laboratory and method QC limits and frequency requirements for blanks, laboratory control samples, replicates, and surrogate and spike recoveries. The initial and continuing calibrations met method requirements, with the exception of the initial calibration response for dibenzo(a,h)anthracene; the responses for dibenzo(a,h)anthracene were above the 120% window for calibration. The dibenzo(a,h)anthracene concentrations were qualified as estimated (i.e., J-qualified) as a result.

CONCLUSIONS

The cPAH TEQs in the clam siphon skin and remainder clam tissue composites were similar based on results from all three clam tissue sampling areas. The data indicate that cPAHs are not preferentially accumulating in siphon skin relative to remainder clam tissue. Therefore, composites of whole-body clam tissue that include siphon skin tissue will be analyzed for cPAHs in the upcoming baseline tissue sampling. The work plan and associated clam tissue quality assurance project plan (QAPP) will reflect this approach.

REFERENCES

Kerns K, Michalsen M, Lotufo GR, Adams K, Duncan B, Hale E. 2017. Controlled field exposures suggest modes of arsenic accumulation in adult eastern softshell clams. Final. US Army Corps of Engineers and US Environmental Protection Agency, Seattle, WA.

PSEP. 1997. Recommended guidelines for sampling marine sediment, water column, and tissue in Puget Sound. Prepared for the Puget Sound Estuary Program, US

Environmental Protection Agency, Region 10. King County (METRO) Environmental Laboratory, Seattle, WA.

Windward. 2007. Lower Duwamish Waterway remedial investigation. Baseline human health risk assessment. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2010. Lower Duwamish Waterway remedial investigation. Remedial investigation report. Final. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward, Integral. 2017. Pre-design studies work plan. Lower Duwamish Waterway Superfund site. Draft. Prepared for the Lower Duwamish Waterway Group for submittal to EPA Region 10. Windward Environmental LLC and Integral Consulting Inc., Seattle, WA.

ATTACHMENT 1. CLAM SAMPLING FOR cPAH ANALYSIS OF SIPHON SKIN MEMORANDUM

MEMORANDUM

To:	LDWG
From:	Windward
Subject:	Clam sampling for cPAH analysis of siphon skin
Date:	June 8, 2017

This memorandum documents the rationale and methods followed in the collection of clams from the Lower Duwamish Waterway (LDW) to assess the relative concentrations of carcinogenic polycyclic aromatic hydrocarbons (cPAHs) in the clam siphon skin relative to the remainder of the clam tissue (referred herein as "main body clam tissue").

PROJECT BACKGROUND AND OBJECTIVES

As discussed in the LDW human health risk assessment (HHRA) and remedial investigation (RI) (Windward 2007, 2010), 95% or more of the arsenic and cPAH risk to human health associated with seafood consumption is from the consumption of clams. The RARE study conducted in the LDW found that inorganic arsenic concentrations detected in siphon skin were significantly higher (19.0 to 65.0 mg/kg wet weight [ww]) than those detected in main body tissue (0.02 to 0.09 mg/kg ww) (Kerns et al. 2017). However, no information is available about the relationship between siphon skin and main body clam tissue for cPAHs.

Thus, in order to determine if there are significant differences in cPAH concentrations between clam siphon skin and main body clam tissue as was the case for inorganic arsenic, clams will be collected from three areas in the LDW with clam habitat and higher cPAH toxic equivalents (TEQs) in sediment. These clams will be sent to the Analytical Resources, Inc. (ARI) for cPAH analysis of siphon skin and main body clam tissue. If analysis of the samples indicates that there are significant differences between cPAH concentrations in clam siphon skin and main body tissue, siphon skin may be analyzed separately in the baseline clam tissue investigation proposed in the Work Plan (Windward and Integral 2017).

STUDY DESIGN AND SAMPLING METHODS

In order to maximize the sampling opportunity, the field crew will collect *Mya arenaria* clams around the low tide (-2.9 ft MLLW) at 1:24 pm on June 26, 2017. Up to 45 *M. arenaria* clams will be collected from two of the clam tissue sampling areas (Table 1) with higher sediment cPAH concentrations identified in Figure 1. Clamming area 3 is publically accessible from the shoreline, but the two locations in clamming area 11 may require access by boat.

Table 1. Clam collection areas

Clamming Area	RM	Coordinates[a]		Property Owner
		Easting (X)	Northing (Y)	
North portion of area 3	0.6 (west)	1265910	208275	Port of Seattle/, northern end of Terminal 107; (area publicly accessible)
North portion of area 11	3.8 (east)	1276041	194978	The Boeing Company, adjacent to Jorgensen Forge
South portion of area 11	3.8 (east)	1276104	194752	The Boeing Company

[a] Coordinates are North American Datum 1983, State Plane Washington North, US survey feet.

RM – river mile

MLLW – mean lower low water

A team with at least two individuals will spend up to 2 hours per location to collect 15 *M. arenaria* clams for analysis at each sampling location. If 10 clams of sufficient size are not collected after one hour, the area may be expanded further along the intertidal beach area while remaining in the area where higher sediment cPAH concentrations were identified. To collect clams, team members will focus their effort by digging for clams with a shovel where clam siphon holes ("shows") or other evidence of clam presence are observed.

Consistent with previous *M. arenaria* collection efforts for the LDW RI (Windward 2004), only intact (i.e., non-broken) clams ≥ 2 cm wide (as measured from valve to valve; Figure 2) will be retained to meet minimum tissue mass requirements for analysis. Broken clams will not be included in the sample. Upon collection, each retained clam will be rinsed in site water to remove any visible sediment and debris. Each clam will be individually wrapped in aluminum foil and all clams from a given area will then be placed in a re-sealable Ziploc bag and put on ice for transport to the laboratory.

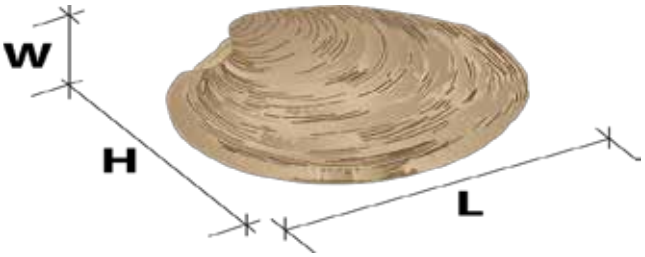


Figure 2. Clam dimension measurements

A Scientific Collection Permit has been obtained from Washington Department of Fish and Wildlife for the collection of these clams. For collection permit reporting purposes, the following data will be recorded on Form 1 (attached) or in the field logbook for each clam encountered, regardless of target species or size:

- Species
- Width (e.g., valve to valve) measurement
- Disposition (e.g., retained for analysis, released at capture site, broken shell)

In addition, a description of the area where clams were collected (including information about sediment type and approximate centroid coordinates) will be recorded on the field forms and/or in the field logbook.

LABORATORY PROCEDURES

Removal of the clam tissue from the shell and separation of the siphon skin from the main body of the clam will be performed at ARI. The technicians will wear nitrile powder-free examination gloves; all sampling equipment will be stainless steel, and will be cleaned between samples to avoid contaminating tissue samples during handling and processing. The laboratory will homogenize and composite siphon skin and main body clam tissue samples. Two composite samples (e.g., one siphon skin and one main body) from 15 clams will be created for each clamming area.

The six composite samples will be analyzed for PAHs using EPA 8270-SIM. Each tissue sample must have a minimum mass of 10g in order to achieve a reporting limit of 5 µg/kg for each PAH compound. Individual clam siphon skins collected as part of the RARE study had masses of 1g on average (K. Kerns pers comm. 2017). Therefore, 15 clams should provide sufficient mass for the clam siphon skin samples.

DATA REPORTING

When the data are available from ARI, they will be summarized in a brief memorandum and submitted to LDWG.

HEALTH AND SAFETY

Potential safety hazards associated with digging for bivalves at intertidal beaches and respective recommended personal protective equipment are discussed below.

Slips and trips

As with all fieldwork sites, caution should be exercised to prevent slips on slick surfaces. In particular, care should be taken on the shoreline or in rainy or wet conditions where slick rocks are found. Trips are also a hazard in the intertidal zone where uneven substrate is common.

Workers should wear water-resistant boots with good tread made of material that does not become overly slippery when wet.

Falling overboard

Intertidal beaches may be accessed from a boat. As with any floating platform, there is always a risk of falling overboard. Workers should exercise caution when boarding and departing from a vessel.

Each worker must wear a personal flotation device (PFD) when travelling on a boat. Boats will also be equipped with a life ring.

Sediment exposure

Previous sediment investigations have shown that some chemical substances may be present at higher-than-background concentrations in the sampling areas. Digging activities will increase the potential for skin exposure to potentially contaminated sediment. General field clothes are usually adequate to minimize exposure to sediment, but impermeable clothing such as rain gear may be worn as a supplement to protect clothing.

Chemical-resistant (e.g., nitrile) gloves will be provided to reduce exposure to workers' hands.

Back strain

Back strain can result if lifting is done improperly. During any manual handling tasks, including digging sediment with a shovel, workers should lift with the load supported by their legs and not their backs.

Emergency Routes to the Hospital

The name, address, and telephone number of the hospital that will be used to provide medical care is as follows (Map 1):

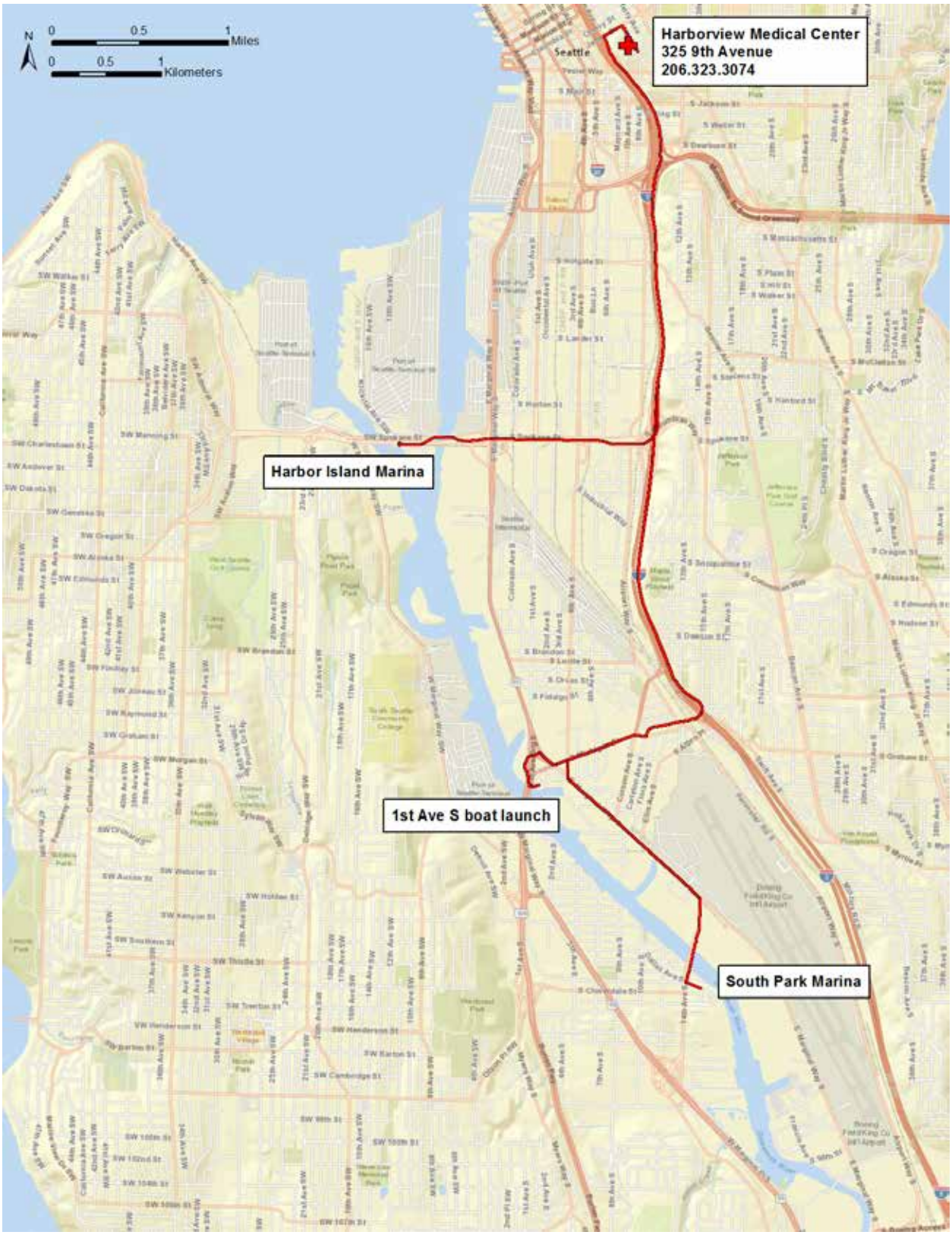
Harborview Medical Center
325 - 9th Avenue
Seattle, WA
206.323.3074

FORM 1. CLAM COLLECTION FORM

LOCATION:			**APPROX. AREA SIZE (FT X FT):**
DATE:			**SUBSTRATE DESCRIPTION:**
CENTROID COORDINATES:			
LAT.	**LONG.**		
START TIME:			**COMMENTS/NOTES:**
STOP TIME:			
CREW:			

#	SPECIES	WIDTH (MM)	DISPOSITION
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
21			
22			
23			
24			
25			

#	SPECIES	WIDTH (MM)	DISPOSITION
26			
27			
28			
29			
30			
31			
32			
33			
34			
35			
36			
37			
38			
39			
40			
41			
42			
43			
44			
45			
46			
47			
48			
49			
50			



Map 1. Emergency routes to Harborview Medical Center

REFERENCES

Kerns K, Michalsen M, Lotufo GR, Adams K, Duncan B, Hale E. 2017. Controlled field exposures suggest modes of arsenic accumulation in adult eastern softshell clams. Draft. Submitted on January 24, 2017. US Army Corps of Engineers and US Environmental Protection Agency, Seattle, WA.

Windward. 2004. Lower Duwamish Waterway remedial investigation. Quality assurance project plan: Benthic invertebrate sampling of the Lower Duwamish Waterway. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2007. Lower Duwamish Waterway remedial investigation. Baseline human health risk assessment. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward. 2010. Lower Duwamish Waterway remedial investigation. Remedial investigation report. Final. Prepared for Lower Duwamish Waterway Group. Windward Environmental LLC, Seattle, WA.

Windward, Integral. 2017. Pre-design studies work plan. Draft. Windward Environmental LLC and Integral Consulting Inc., Seattle, WA.

ATTACHMENT 2. DATA TABLES

Table A1. Clam width and mass summary

Site Name	Clam No.	Width (cm)	Remainder Mass (g)	Siphon Skin Mass (g)
C06	1	3.1	12.57	2.69
C06	2	2.8	16.82	2.48
C06	3	3.0	12.38	2.65
C06	4	3.5	16.80	2.99
C06	5	3.1	15.71	2.54
C06	6	3.0	21.48	2.60
C06	7	3.3	15.27	2.55
C06	8	2.9	9.85	1.71
C06	9	2.9	14.26	1.82
C06	10	3.5	19.61	4.73
C06	11	3.1	18.97	2.39
C06	12	2.7	6.31	1.56
C06	13	2.6	9.92	1.49
C06	14	2.7	23.60	2.67
C06	15	2.8	11.34	1.87
C06 composite mass			**224.89**	**36.74**
C11N	1	3.1	16.04	5.66
C11N	2	2.4	11.25	2.52
C11N	3	2.7	8.74	2.41
C11N	4	3.4	21.42	4.35
C11N	5	2.9	13.88	3.60
C11N	6	3.1	14.54	2.86
C11N	7	3.4	32.70	8.33
C11N	8	3.1	20.95	3.74
C11N	9	3.0	16.69	5.02
C11N	10	2.8	26.44	4.21
C11N	11	2.5	8.42	1.63
C11N	12	3.1	14.71	2.93
C11N	13	2.9	25.72	3.82
C11N	14	2.7	11.46	2.94
C11N	15	3.0	15.46	3.34
C11N composite mass			**258.42**	**57.36**

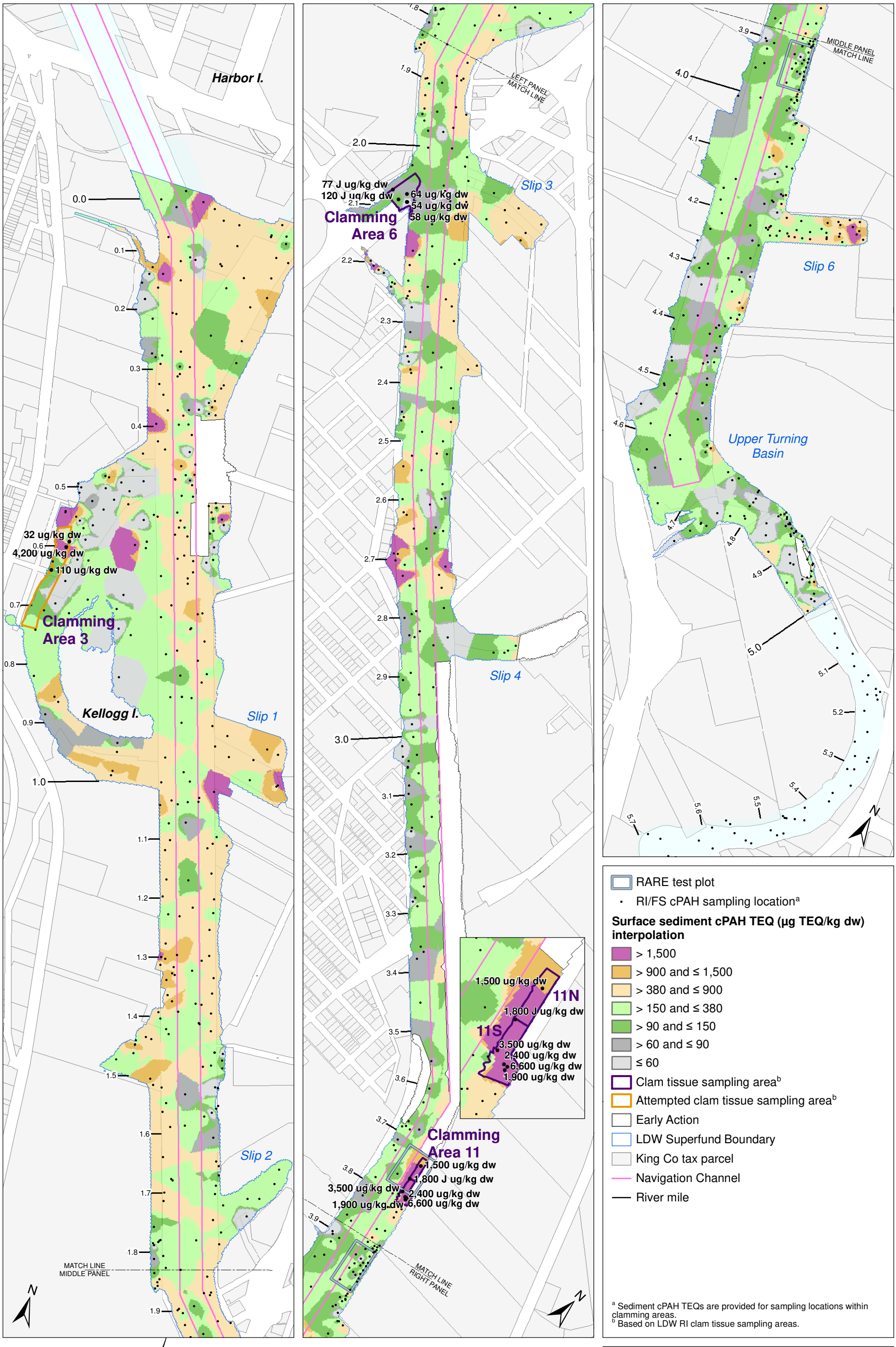
Site Name	Clam No.	Width (cm)	Remainder Mass (g)	Siphon Skin Mass (g)
C11S	1	2.6	18.47	2.77
C11S	2	2.9	14.00	2.38
C11S	3	2.3	16.24	2.42
C11S	4	3.1	15.04	4.08
C11S	5	2.6	11.49	2.09
C11S	6	2.9	16.04	4.29
C11S	7	2.2	14.18	2.7
C11S	8	3.0	13.96	2.67
C11S	9	3.3	18.32	3.28
C11S	10	2.6	17.20	1.83
C11S	11	2.4	8.73	2.62
C11S	12	3.1	16.33	2.68
C11S	13	2.8	19.12	3.14
C11S	14	3.1	18.63	2.62
C11S	15	2.8	16.85	4.12
C11S composite mass			**234.60**	**43.69**

Table A2. Clam siphon tissue

Chemical	Unit	Location C06		Location C11N		Location C11S	
		Sample LDW17-C06-MARM-Comp01	Sample LDW17-C06-MAST-Comp01	Sample LDW17-C11N-MARM-Comp01	Sample LDW17-C11N-MAST-Comp01	Sample LDW17-C11S-MARM-Comp01	Sample LDW17-C11S-MAST-Comp01
		Remaining	Siphon	Remaining	Siphon	Remaining	Siphon
		6/26/2017	6/26/2017	6/26/2017	6/26/2017	6/26/2017	6/26/2017
PAHs							
1-Methylnaphthalene	µg/kg ww	0.48 U	0.49 U	0.47 U	0.49 U	0.49 U	0.49 U
2-Methylnaphthalene	µg/kg ww	0.48 U	0.49 U	0.47 U	0.49 U	0.49 U	0.49 U
Acenaphthene	µg/kg ww	1.33	0.49 U	1.04	0.49 U	0.87	0.49 U
Acenaphthylene	µg/kg ww	0.48 U	0.49 U	0.47 U	0.49 U	0.49 U	0.49 U
Anthracene	µg/kg ww	1.34	0.50	1.24	0.97	0.97	0.58
Benzo(a)anthracene	µg/kg ww	6.80	1.84	5.53	5.11	4.62	3.37
Benzo(a)pyrene	µg/kg ww	3.32	2.10	2.88	5.86	2.33	3.64
Benzo(b)fluoranthene	µg/kg ww	4.59	2.97	4.02	7.20	3.03	4.12
Benzo(g,h,i)perylene	µg/kg ww	8.57	2.53	7.90	6.91	5.42	3.87
Benzo(j)fluoranthene	µg/kg ww	2.02	1.23	1.78	3.29	1.41	1.87
Benzo(k)fluoranthene	µg/kg ww	2.43	1.32	2.17	3.66	1.95	2.05
Total benzofluoranthenes - zero DL	µg/kg ww	9.04	5.52	7.97	14.15	6.39	8.04
Chrysene	µg/kg ww	8.63	2.74	7.24	7.35	5.77	4.26
Dibenzo(a,h)anthracene	µg/kg ww	0.54 J	0.52 J	0.47 U	1.72 J	0.49 U	1.07 J
Dibenzofuran	µg/kg ww	0.73	0.49 U	0.60	0.49 U	0.51	0.49 U
Fluoranthene	µg/kg ww	20.3	4.85	16.4	20.0	14.4	8.99
Fluorene	µg/kg ww	1.39	0.49 U	1.12	0.49 U	0.89	0.49 U
Indeno(1,2,3-cd)pyrene	µg/kg ww	1.58	1.91	1.44	5.97	1.11	3.30
Naphthalene	µg/kg ww	0.58 U	0.59 U	0.56 U	0.59 U	0.58 U	0.59 U

Chemical	Unit	Location C06		Location C11N		Location C11S	
		Sample LDW17-C06-MARM-Comp01	Sample LDW17-C06-MAST-Comp01	Sample LDW17-C11N-MARM-Comp01	Sample LDW17-C11N-MAST-Comp01	Sample LDW17-C11S-MARM-Comp01	Sample LDW17-C11S-MAST-Comp01
		Remaining	Siphon	Remaining	Siphon	Remaining	Siphon
		6/26/2017	6/26/2017	6/26/2017	6/26/2017	6/26/2017	6/26/2017
Phenanthrene	µg/kg ww	7.12	1.56	5.29	4.75	4.60	3.30
Pyrene	µg/kg ww	16.9	4.63	15.4	15.2	13.4	7.92
Total HPAHs	µg/kg ww	75.7 J	26.64 J	64.8	82.3 J	53.4	44.46 J
Total LPAHs	µg/kg ww	11.18	2.06	8.69	5.72	7.33	3.88
Total PAHs	µg/kg ww	86.9 J	28.70 J	73.5	88.0 J	60.8	48.34 J
cPAHs 2005 - mammal (half DL)	µg/kg ww	5.0 J	3.0 J	4.3	8.3 J	3.5	5.1 J
Other SVOCs							
2-Chloronaphthalene	µg/kg ww	0.48 U	0.49 U	0.47 U	0.49 U	0.49 U	0.49 U
Benzothiophene	µg/kg ww	0.48 U	0.49 U	0.47 U	0.49 U	0.49 U	0.49 U
Conventionals							
Lipid	% ww	0.86	0.037	1.0	0.068	0.89	0.060
Total solids	% ww	13.4	16.8	14.8	18.5	13.8	17.3

cPAH – carcinogenic polycyclic aromatic hydrocarbon
DL – detection limit
HPAH – high-molecular-weight polycyclic aromatic hydrocarbon
J – estimated concentration
LPAH – low-molecular-weight polycyclic aromatic hydrocarbon
PAH – polycyclic aromatic hydrocarbon
SVOC – semivolatile organic compound
U – not detected at given concentration
ww – wet weight


Harbor I.
Kellogg I.
Slip 1
Slip 2
Slip 3
Slip 4
Slip 6
Upper Turning Basin
Clamming Area 3
Clamming Area 6
Clamming Area 11
77 J ug/kg dw
120 J ug/kg dw
64 ug/kg dw
54 ug/kg dw
58 ug/kg dw
32 ug/kg dw
4,200 ug/kg dw
110 ug/kg dw
1,500 ug/kg dw
1,800 J ug/kg dw
3,500 ug/kg dw
2,400 ug/kg dw
6,600 ug/kg dw
1,900 ug/kg dw
11N
11S
LEFT PANEL MATCH LINE
MIDDLE PANEL MATCH LINE
MATCH LINE MIDDLE PANEL
MATCH LINE RIGHT PANEL
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
2.1
2.2
2.3
2.4
2.5
2.6
2.7
2.8
2.9
3.0
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
3.9
4.0
4.1
4.2
4.3
4.4
4.5
4.6
4.7
4.8
4.9
5.0
5.1
5.2
5.3
5.4
5.5
5.6
5.7
N
RARE test plot
RI/FS cPAH sampling location[a]
Surface sediment cPAH TEQ (µg TEQ/kg dw) interpolation
> 1,500
> 900 and ≤ 1,500
> 380 and ≤ 900
> 150 and ≤ 380
> 90 and ≤ 150
> 60 and ≤ 90
≤ 60
Clam tissue sampling area[b]
Attempted clam tissue sampling area[b]
Early Action
LDW Superfund Boundary
King Co tax parcel
Navigation Channel
River mile
[a] Sediment cPAH TEQs are provided for sampling locations within clamming areas.
[b] Based on LDW RI clam tissue sampling areas.
0 0.1 0.2 Miles
0 0.2 0.4 Kilometers
Scale is the same for each inset map
Windward environmental LLC
Lower Duwamish Waterway Group
Port of Seattle / City of Seattle / King County / The Boeing Company
Map 1. Clam sampling areas to assess cPAH TEQs in clam siphon skin tissue relative to remaining clam tissue
DRAFT
Prepared by craigh, 8/7/2017; W:\Projects\Duwamish AOC3\GIS\Maps and Analyses\Task 01 Work Plan\Clam Siphon Memo\Map 1 6603 ENRAC-RARE cPAHs - lbld.mxd